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Potential energy savings by radiative cooling system for a building in tropical climate

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A R T I C L E I N F O

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A B S T R A C T

Nowadays, almost every building required a cooling system and most of them use active cooling, which normally operates using electricity generated from non-renewable fossil fuel. To achieve comfort, it is possible to utilize the natural environmental conditions to partially replace the active cooling energy requirements. This research attempts to investigate the correlation between the radiative cooling power and the temperature difference between the ambient and the sky. The potential of a radiative cooling system in Malaysia is evaluated as well. The radiative cooling system operates by using a flat-plate rooftop as a radiator to reject heat to the cooler nocturnal sky for cooling purposes. In addition, the radiative cooling potential is determined by using the climate data of 10 different locations in Malaysia. The study found that radiative cooling can save up to 11% of the power consumption for cooling purposes. This value is the same for all 10 locations in this country.

Contents

1. Introduction

Nowadays, a subsequent amount of energy is consumed in buildings and it leads us to concentrate on energy saving in this sector. Meanwhile, cooling and heating play a major role in energy consumption of buildings. Based on this reason, extensive research has been done to improve the efficient use of energy in buildings.

In the energy management of buildings, there are some factors discussed in the literature. These include utilizing low-energy consuming systems such as absorption cooling systems, thermal energy storage, cooling storage, off-peak cooling and ice storage [1–15], utilizing day-lighting method to reduce lighting appliances during day [16–18,19], phase change materials [20–23], heat pump

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Nomenclature

T_f	fluid temperature (°C)
T_a	ambient air temperature (°C)
T_{fi}	fluid temperature at collectors inlet (°C)
S	absorbed solar energy (W/m^2)
U_L	overall heat loss coefficient of the collector (W/m^2 °C)
n	number of pipes
W	distance between the pipe (m)
F	collector efficiency factor
y	distance from collector inlet (m)
$\dot{m}$	mass flow rate through the collector (kg/s)
C_P	specific heat of the fluid (J/kg °C)
C_b	bond conductance between the pipes and absorber plate (W/m °C)
h_{fi}	heat transfer coefficient between the fluid and the tube interior (W/m^2 °C)
D	external diameter of the pipe (m)
D_i	internal diameter of the tube (m)
F	fin efficiency factor
W	riser spacing (m)
δ	fin thickness (m)
K	thermal conductivity of the fin (W/m °C)
A	area of radiator (m^2)
εr	radiator emissivity coefficient
σ	Stephan–Boltzman constant (5.67051×10^{-8} Wm^{-2}K^{-4})
T_{rad}	radiator min temperature (K)
T_{sky}	sky temperature (K)
ε_{sky}	sky emissivity
α_W	alpha parameter for shape of weather tower
H_W	height of weather tower (m)
γ_W	gamma parameter for shape of weather tower
α_C	alpha parameter for shape of test cell
H_C	height of test cell
γ_C	gamma parameter for shape of test cell
v	wind velocity at test field (m/s)
C_{sys}	heat capacity of the cooling system (kJ K^{-1})
K_{sys}	system total heat capacity loss rate except radiator (W K^{-1})
P_{pump}	heat transfer from pump to water (75% of pump electrical usage

systems [24], optimum thermal design in buildings [25], automation systems and controlled ventilation [26–29], appliance standards [30], thermal comfort systems [31–33], and utilizing sources of renewable energy such as wind energy and solar radiation [1,34–43].

As Malaysia is located in tropical climate, energy consumption of cooling units in buildings has an essential role in energy savings. Due to this, various measures to reduce the cooling loads have been introduced. Reduction of cooling loads can be carried out in relation to windows such as smart windows [44], optimum overhang dimensions [45], optimum size of windows [46], and thermal insulation [47,48]. In addition to windows, insulation of building envelopes [49–51], high-albedo roofs [52,53], solar reflectance roofs [54–56], green roofs [57–60], shading effects [58,59,61–63], using skytherm and cooled ceiling systems [55,64–66], passive cooling systems in buildings [67–71], natural ventilation [72–74], and thermal mass [75,76] are the other factors that were analyzed previously, to reduce the cooling loads in buildings.

As mentioned above, there are various ways of reducing the cooling loads. Meanwhile, a radiative cooling system has the potential to improve enegry efficiency of cooling load in buildings.

In general, radiation is the condition where energy is transmitted in the form of an electromagnetic wave due to change in an object's atomic or molecular configuration. In the field of heat transfer, thermal radiation refers to energy transmitted by an object to the surroundings because of the temperature difference between the object and the surroundings. The object's temperature will drop resulting from loss of energy. The concept of thermal radiation has been used in cooling of a human body [77].

The radiative cooling technique is based on the principle of heat transfer by long-wave radiation emission from a high temperature object to a lower one. In this study, a building's rooftop is used as a medium to reject heat to the night sky in order to reduce the energy consumption for space cooling. The cooling object is the roof surface and the night sky is the heat sink because the temperature of the night sky is lower than most of the earth bound objects. Long-wave radiation is a continuous day and night process. In daylight, a long-wave transmitter is exposed to solar radiation and hence will absorb more heat rather than reject it. Therefore, radiative cooling can only operate at night [77].

According to the research, a night sky radiative cooling system has a great potential in reducing the energy consumption for space cooling [77]. The system consists of a transmitter or a radiator which is made of a high conductivity flat-plate rooftop where water is circulated in it and allowed heat transfer from the water to the rooftop or radiator and then radiated to the night sky [78]. Water is a good heat carrier and it will absorb the heat from the room space when cooling water from radiative cooling is circulated through the pipeline in the ceiling and wall. This system can reduce the cooling load for an air-conditioning room. In case of energy saving, this system operates under the principle of passive cooling and it is cost free. Therefore, this cooling system is an effective technology in improving the quality of indoor air and also in saving energy [79].

In this modern era, space cooling is a necessity for comfort and hence results in high energy consumption. Nowadays, almost every building required a cooling system and most of them use active cooling which normally operates using electricity derived from non-renewable fossil fuel. This non-renewable fossil fuel price is increasing and it will cost a lot for the purpose of space cooling. The increase in energy consumption will also lead to high greenhouse gas emission. Instead of investing in non-renewable energy to achieve comfort, it is possible to use the natural environmental conditions to partially replace the active cooling energy requirements [77].

Energy consumption can be reduced if some of the cooling load is replaced by passive cooling techniques. Radiative cooling is a passive cooling method, which is based on long-wave radiation emission to reject heat to the night sky. Numerous studies on radiative cooling in buildings have been conducted, and most of the systems use air [80] or water [81] as a heat carrier. The system consists of a transmitter or a radiator panel. The radiator is made of a high conductivity flat-plate in which air or water is circulated and allowed heat to transfer from the heat carrier to the rooftop and hence radiated to the sky. The air or water is circulated using a low power density pump [82]. The system's effectiveness is dependent on certain parameters such as dew point temperature, ambient air temperature, wind velocity, and relative humidity [82]. While many studies have been conducted, its commercial exploitation is still untapped [83]. This research investigates the correlation between the radiative cooling power and the temperature difference between the ambient and the sky. The parameter that influences the effectiveness of the radiative cooling system is also examined.

2. Methodology

To study the correlation of cooling power and temperature difference between ambient and sky temperatures, climate data need to be available. The important data are the ambient temperature and dew point temperature. Then a mathematical model will be developed to determine the sky temperature and hence calculate the cooling power. Analysis is conducted on two different sky conditions to study the correlation between sky condition and cooling power. Then the radiative cooling system's potential can be predicted. This is done by using the climate data of 10 different locations in Malaysia.

2.1. Climate data

To be able to do the radiative cooling analysis, climate data such as ambient air temperature and dew point temperature need to be available. This climate data is collected from the meteorological site. The data given is in graph form with daily high and low temperatures and daily high and low dew point temperatures. For analysis purposes, the data collected are the daily low temperature and daily dew point temperature. This is because the system is operating during night and the ambient and dew point temperatures are at the lowest value during the night.

2.2. Radiation heat transfer

A mathematical model of radiative cooling was developed based on radiation phenomena of all surfaces to the nocturnal sky by radiation heat transfer. In this research, heat loss from an uncover radiator surface is due to radiation and convection. Heat transfer by conduction between the radiator and the surroundings is neglected. Therefore, the equation of power can be written as [84]

$$P_C = P_{Rad} + P_{conv} \tag{1}$$

where P_c is the total cooling power, P_{conv} is the cooling power by convection and P_{rad} is the cooling power by long-wave radiation, and P_{rad} is given by [84]

$$P_{rad} = A \,.\, \varepsilon r(\sigma T_{rad}^4 - R) \tag{2}$$

R represents the long-wave radiation that is received by the radiator surface. For a flat surface, long-wave radiation is due to an atmospheric layer close to the earth's surface ($R = R_a$). Ambient temperature, T_a, which is close to the earth's surface, represents this atmospheric layer. Sky temperature, T_{sky}, is introduced to explain the atmospheric radiation heat transfer. It is defined as black body temperature when it emits radiation power equal to that of the sky based on the Stefan–Boltzman law [84]

$$R_A = \sigma . T_{sky}^4 = \sigma . \varepsilon . T_a^4 \tag{3}$$

Therefore Eq. (2) will be

$$P_{rad} = A . \varepsilon r . \sigma (T_{rad}^4 - T_{sky}^4) \tag{4}$$

The radiator temperature is usually equal to the ambient temperature. The sky temperature can be measured using an infra-red thermometer, but in this research, the sky temperature will be determined using an equation suggested by a previous researcher [85]

$$T_{sky} = \varepsilon_{sky}^{1/4} T_{air} \tag{5}$$

$$\varepsilon_{sky} = 0.006 T_{dp} + 0.74 \tag{6}$$

2.3. Convection heat transfer

In the case of a radiator thermal equilibrium, heat transfer from the roof to the surroundings needs to be accounted for. Based on the previous research, it is known that this factor has a great effect on the radiative cooling system. Constant approximation of convection heat transfer of the roof is made by assuming turbulent flow over the radiator surface. The convection heat transfer equation is as below [84]

$$P_{conv} = h_{conv} . A (T_s - T_a) \tag{7}$$

In the previous research, most of the time operation temperature is more than ambient air temperature. Therefore, heat loss due to convection provided a positive contribution to total heat loss.

For a surface without a wind-screen, convection coefficient h_{conv} is the first order for linear function of wind speed, v, and in the form of $h_{conv} = a + b.v$. A previous study shows that there is a large distribution of values a and b. An equation developed by Clark and Berdahl [86] is modified for forced convection by Duffie and Beckmann [85] and used to find the experimental data. The most appropriate equation is introduced by Ernani Sartori [87]

$$h_{conv} = 3.1 + 4.1 v \; [\mathrm{Wm^{-2}\,K^{-1}}] \tag{8}$$

Parameter v is the wind velocity where it ranges between 0.1 ms^{-1} and 2.0 ms^{-1}, and the average value is 0.8 ms^{-1} in the previous study. Determination of wind velocity can be found by using the relationship proposed by Sherman [88] which changes wind velocity recorded from a weather tower to wind velocity at the roof surface. The equation is as follows:

$$v' = \{\alpha_W [(H_W/10)\gamma_W] / [\alpha_C (H_C/10)\gamma_C]\} \times v \tag{9}$$

2.4. Calculation of cooling system power

Cooling power, $P_{c,exp}$, of a radiator is determined by a change in the system temperature, T_{sys}, over time (dT/dt) and improved by taking into consideration the additional or incremental heat from water reservoir, pipe and surroundings as below

$$P_{c.exp} = -C_{sys} . \left(\frac{dT}{dt}\right)_{sys} - K_{sys} . (T_{sys} - T_{indoor}) + P_{pump} \tag{10}$$

3. Results and discussion

To determine the cooling power, a few parameters need to be identified in order to perform the analysis. These important parameters are the radiator emissivity coefficient, radiator temperature and sky temperature. In this study only theoretical analysis will be provided.

In order to determine the correlation between the sky temperature and the cooling power, the ambient and dew point temperatures are taken from climate data [89]. The sky temperature is calculated using Eqs. (5) and (6). From these available values, the cooling power for radiative cooling system can be evaluated. Then the graph will be plotted to represent the relationship between the cooling power and the temperature difference between ambient and sky temperatures.

3.1. Determination of cooling power

The unit of the cooling power is W/m^2 which is power dissipated per unit area. The radiator emissivity coefficient is taken as 0.8 as the radiator is assumed to be bronze painted [90]. The radiator surface temperature is usually the same as the ambient air temperature. Using the available climate data for certain locations in Malaysia, the radiator temperature is assumed to be equal to ambient temperature. From the climate data, the dew point temperature is also

available. The dew point temperature is used to determine the sky temperature using Eqs. (5) and (6).

Sample calculation:

At 2/12/12, given that $T_{dp}=23$ °C and the air temperature at 8.p.m = 27 °C.

Sky temperature:

$$\varepsilon_{sky}=0.006T_{dp}+0.74$$

$$\varepsilon_{sky}=0.006(23)+0.74$$

$$\varepsilon_{sky}=0.878$$

$$T_{sky}=\varepsilon_{sky}^{1/4}T_{air}$$

$$T_{sky}=(0.878^{1/4}(273+27)$$

$$T_{sky}=290.4\ K$$

Cooling power:

$$P_{rad}=\varepsilon r.\sigma(T_{rad}^4-T_{sky}^4)$$

$$P_{rad}=(0.8)(5.67051\times10^{-8})([273+27]^4-290.4^4)$$

$$P_{rad}=44.83\ W/m^2$$

The cooling power analysis is conducted on different sky and ambient temperatures to understand the relationship of temperature difference between ambient and sky temperatures and cooling power.

According to Table 1:

$$\text{Average } T_a-T_{sky}=9.55\ °C,\quad \text{average cooling power}=43.9\ \text{W/m}^2$$

According to climate data [89], the weather condition on this day is starting with warm clouds passing by and light rain. This condition had affected the dew point temperature and the sky temperature. Therefore, the cooling power obtained is intermediate.

Fig. 1 shows a graph of cooling power against (T_a–T_{sky}) on 2 December 2012 [89]. From the above graph, it is shown that the cooling power is decreasing as the temperature difference is getting smaller. Because there is no big difference between ambient and sky temperatures, the radiator can only radiate a small amount of heat to the sky. The correlation value for the graph above is 0.99998. This indicates that the temperature difference between the ambient and the sky has almost perfect correlation with cooling power.

According to Table 2:

$$\text{Average } T_a-T_{sky}=10.53\ °C,\quad \text{average cooling power}=48\ \text{W/m}^2$$

Table 1
Cooling power for different T_a–T_{sky} on 2 December 2012.

Date: 2/12/2012 dew point = 23 °C				
Time	**T_a (°C)**	**T_{sky} (°C)**	**T_a–T_{sky} (°C)**	**Cooling power (W/m²)**
20:00	27.0	17.4	9.60	44.8
21:00	27.0	17.4	9.60	44.8
22:00	26.3	16.7	9.58	44.4
23:00	26.0	16.4	9.57	44.2
0:00	25.5	15.9	9.55	43.9
1:00	25.5	15.9	9.55	43.9
2:00	25.2	15.7	9.54	43.7
3:00	25.0	15.5	9.54	43.6
4:00	24.4	14.9	9.52	43.2
5:00	24.3	14.8	9.51	43.2
6:00	24.0	14.5	9.51	43.0

The weather condition for this day is quite good. The sky is partially covered by clouds. But because the relative humidity is high, the dew point temperature is quite high. Therefore the cooling power obtained is considered high.

Fig. 2 shows a graph of cooling power against (T_a–T_{sky}) on 13 December 2012 [89]. It was found that the cooling power obtained is high. This is because there is a big difference between the air temperature and the sky temperature. Therefore, the radiator can reject a large amount of heat to the cooler sky. The correlation value for Fig. 2 is 0.99998. This indicates that the temperature difference between the ambient and the sky almost perfectly correlates with cooling power.

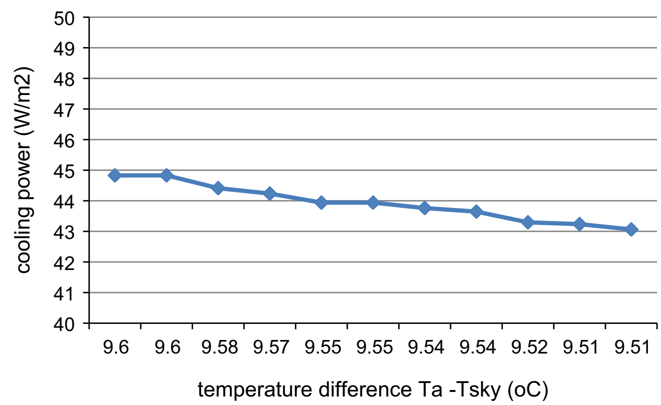

Fig. 1. Cooling power against (T_a–T_{sky}) on 2 December 2012.

Table 2
Cooling power for different T_a–T_{sky} on 13 December 2012.

Date: 13/12/2012 dew point = 21 °C				
Time	**T_a (°C)**	**T_{sky} (°C)**	**T_a–T_{sky} (°C)**	**Cooling power (W/m²)**
20:00	27.0	16.4	10.60	49.2
21:00	27.0	16.4	10.60	49.2
22:00	26.0	15.4	10.56	48.6
23:00	26.0	15.4	10.56	48.6
0:00	25.5	15.0	10.55	48.3
1:00	25.0	14.5	10.53	47.9
2:00	24.5	14.0	10.51	47.6
3:00	24.0	13.5	10.49	47.3
4:00	24.0	13.5	10.49	47.3
5:00	23.8	13.3	10.49	47.2
6:00	23.0	12.5	10.46	46.7

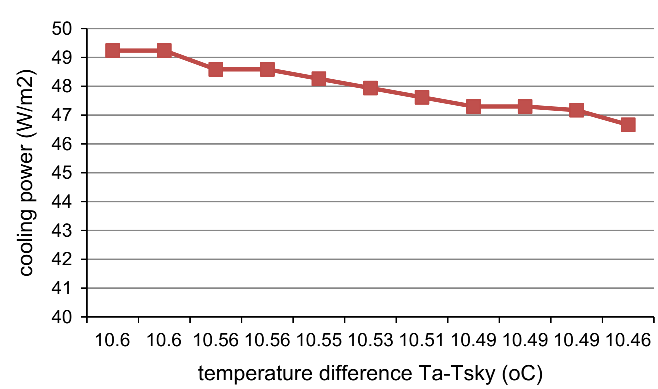

Fig. 2. Cooling power against (T_a–T_{sky}) on 13 December 2012.

3.2. Relationship between cooling power and temperature difference

This section discusses the relationship between the cooling power and the sky temperature. This relationship will be shown and explained based on the graph that has been plotted in Figs. 1 and 2. From the graph, the correlation between cooling power and temperature difference between the ambient and the sky can be analyzed. The results show that cooling power is directly proportional to temperature difference. An increase in temperature difference will increase the cooling power. This occurs because the radiator can reject more heat to the cooler sky. The cooling surface is the radiator surface and the heat sink is the nocturnal sky as its temperature is lower than the radiator which is an earth bound object. So the sky will absorb more heat from the radiator and hence increase the cooling power.

The results show that the cooling power is higher on 13 December 2012 with an average cooling power of 48 W/m^2 when the average temperature difference is 10.5 °C. The cooling power obtained is high because the sky is clear with almost no cloud cover. But on 12th December 2012, the average cooling power obtained is only 43.9 W/m^2 when the average temperature difference is only 9.5 °C. This is due to the overcast clouds that covered

Table 3
Ambient, sky, and dew point temperatures and cooling power estimation for Subang Jaya in year 2012.

Month	T_a (°C)	T_{dp} (°C)	T_{sky} (°C)	Cooling power (W/m^2)
January	24.0	22.0	14.0	45.2
February	24.5	21.5	14.2	46.6
March	24.9	22.5	15.1	44.7
April	25.2	23.0	15.7	43.8
May	25.3	22.8	15.7	44.2
June	24.8	22.3	14.9	45.0
July	24.5	22.0	14.5	45.5
August	24.3	21.9	14.2	45.6
September	24.2	22.0	14.2	45.3
October	24.2	22.2	14.3	44.9
November	24.0	22.6	14.3	43.9
December	24.1	22.3	14.2	44.6

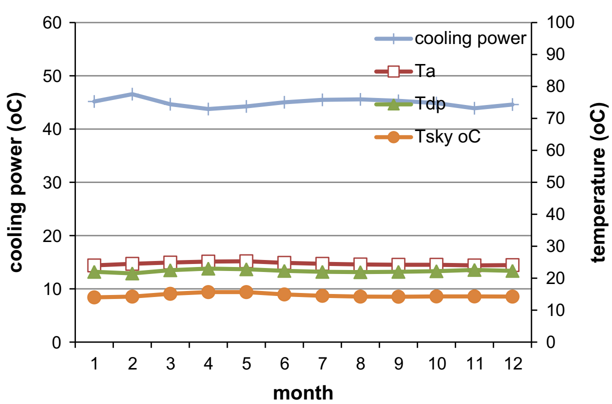

Fig. 3. Cooling power, ambient, dew point and sky temperatures against month in the year 2012 for Subang Jaya.

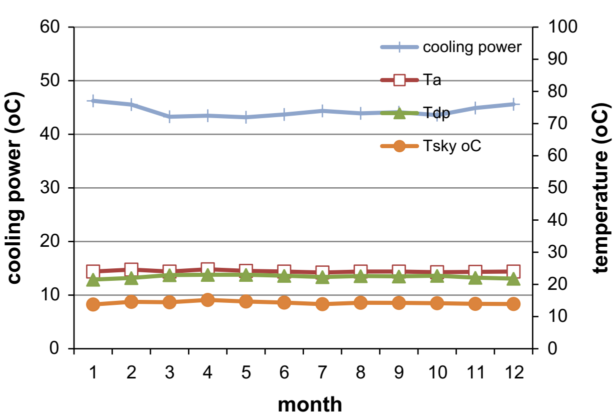

Fig. 4. Cooling power, ambient, dew point and sky temperatures against month in the year 2012 for Melaka.

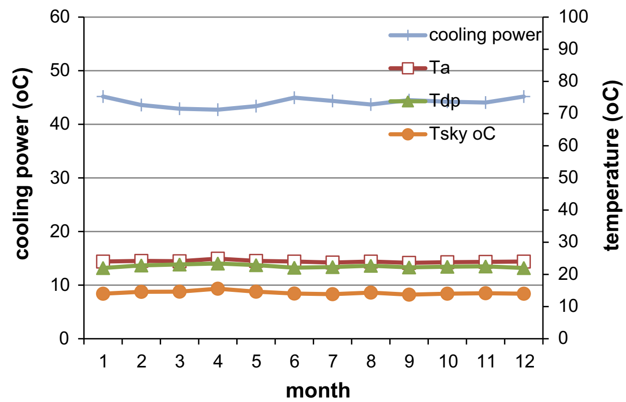

Fig. 5. Cooling power, ambient, dew point and sky temperatures against month in the year 2012 for Kuala Terengganu.

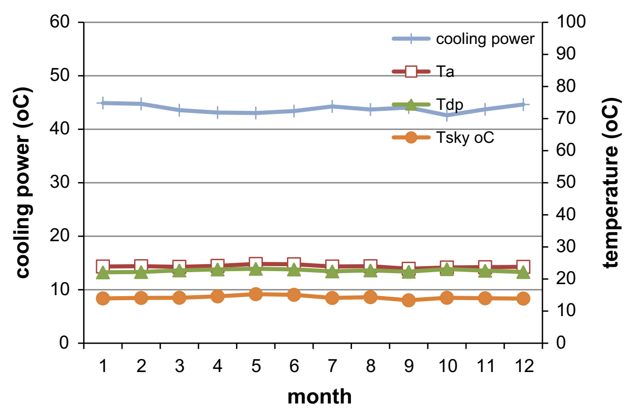

Fig. 6. Cooling power, ambient, dew point and sky temperatures against month in the year 2012 for Sepang.

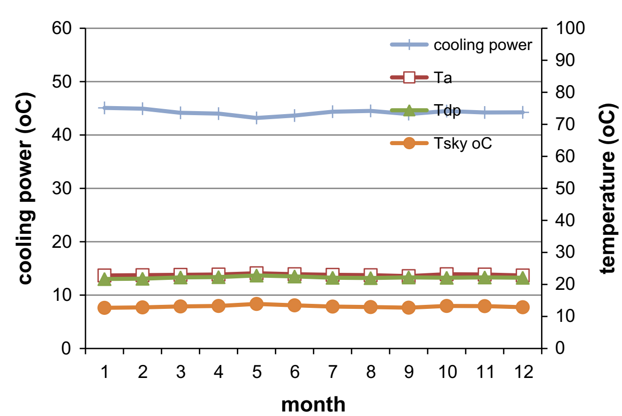

Fig. 7. Cooling power, ambient, dew point and sky temperatures against month in the year 2012 for Johor.

the sky. Therefore, less heat can be rejected to the sky. The temperature difference and cooling power are directly related or directly proportional. This is due to the correlation between the two variables is almost 1 which is 0.99.

3.3. *Estimation of cooling power potential in Malaysia*

The estimation of cooling power potential for several locations in Malaysia is investigated. The estimation is conducted by using the available climate data and using the mathematical model. The radiator used is a modified flat-plate solar collector that is available in market. In order to estimate the cooling power potential, the radiator area is assumed as 2 m × 3 m which is the size of a standard flat-plate solar collector. The average HVAC power consumption for a standard residential area is 1 kWh. If the standard air-conditioning unit is operated in the night, it consumed about 1 kW. The electrical pump used is assumed as 60 W. By multiplying the cooling power (W/m^2) with the radiator area, the radiative cooling system contribution in energy saving can be determined. By using the climate data available (average weather for subang jaya, weather park), the estimation of cooling power potential can be evaluated.

3.3.1. *Summary of radiative cooling potential in Malaysia*

The radiative cooling power can be estimated by using the climate data such as ambient, dew point and sky temperatures. All the climate data and the cooling power estimation are simplified and tabulated in table. Table 3 is an example of tabulated data for Subang Jaya.

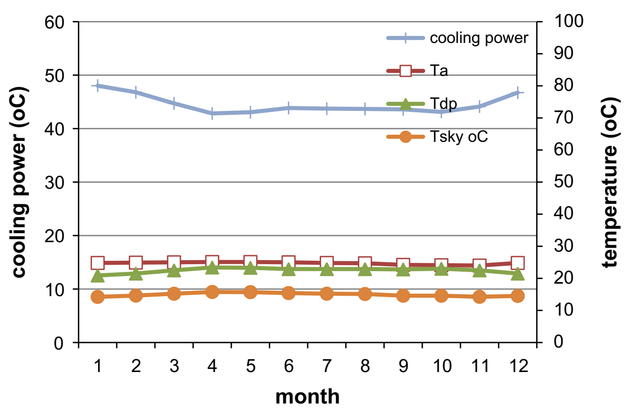

Fig. 8. Cooling power, ambient, dew point and sky temperatures against month in the year 2012 for George Town.

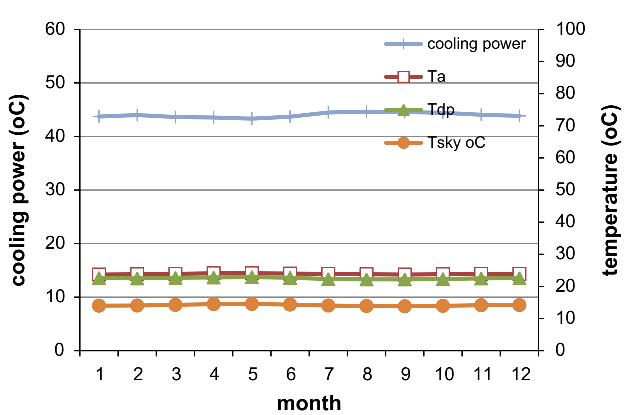

Fig. 9. Cooling power, ambient, dew point and sky temperatures against month in the year 2012 for Bintulu.

To show a clear relationship between those parameters, a graph was plotted.

All the climate data and the estimation of radiative cooling power for all major places are shown in (Figs. 3–12).

All the figures show the graph of cooling power, ambient, dew point and sky temperatures against the month throughout year 2012 for 10 major cities in Malaysia. The average cooling power for the whole year of 2012 is determined and the value is in the range of 43–45 W/m^2. The graphs indicate that there is no significant change in weather condition. The cooling power obtained is

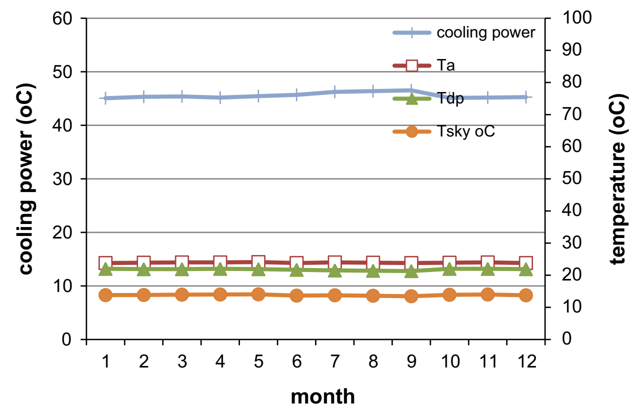

Fig. 10. Cooling power, ambient, dew point and sky temperatures against month in the year 2012 for Kota Kinabalu.

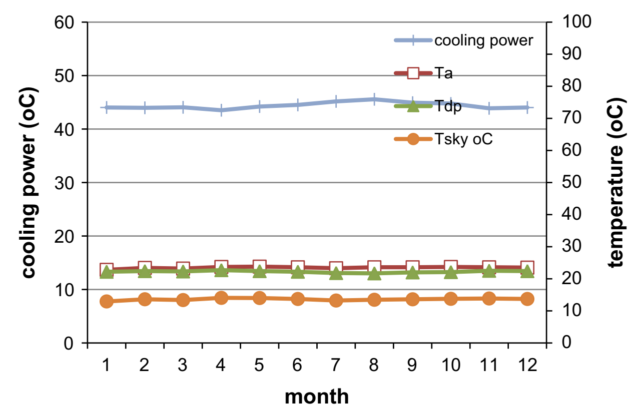

Fig. 11. Cooling power, ambient, dew point and sky temperatures against month in the year 2012 for Kuching.

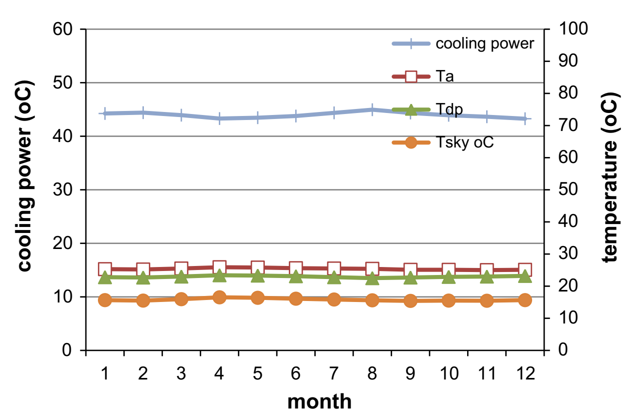

Fig. 12. Cooling power, ambient, dew point and sky temperatures against month in the year 2012 for Labuan.

considered moderate. This is due to the location area which is mostly covered with croplands, oceans and seas and forest.

Then the percentage of radiative cooling power contribution for cooling purposes is determined. This will show how much the radiative cooling system can reduce energy consumption in achieving cooling comfort. The power consumption by a water pump is included in the calculation of energy savings.

Sample calculation (Labuan):

$P_{HVAC} = 1$ kW

$A = 2 \times 3 = 6$ m^2

$P_{pump} = 60$ W

Cooling power contribution from the radiator:

$P_{cooling}' = P_{cooling} \times A$

$P_{cooling}' = 43.97 \times 6 = 263.82$ W

Percentage of energy savings:

$$\frac{P_{cooling}'}{P_{HVAC} + P_{pump}} \times 100\% = \frac{263.82}{1000 + 60} \times 100\% = 24.9\%$$

The percentage of energy savings for all major cities is determined and tabulated in Table 4.

To give a clearer picture of the radiative cooling potential in Malaysia, a graph is plotted based on Table 4 and presented in Fig. 13.

Based on Fig. 13 the average cooling power for 10 different cities is in the range of 43–45 W/m^2, while the percentage of energy savings is in the range of 24–26%. From these results, it can be concluded that the radiative cooling system has a potential in saving more than 25% power consumption for space cooling purposes.

Table 4
Average cooling power and percentage of energy savings for 10 different locations throughout Malaysia.

Location	Average cooling power (W/m^2)	Percentage of energy savings (%)
Subang Jaya	44.93	11.20
Melaka	44.32	11.01
Kuala Terengganu	44.07	10.95
Sepang	43.82	10.89
Johor	44.23	10.99
George Town	44.53	11.07
Bintulu	44.00	10.93
Kota Kinabalu	45.57	11.32
Kuching	44.39	11.03
Labuan	43.97	10.93
Subang Jaya	44.93	11.20
Melaka	44.32	11.01

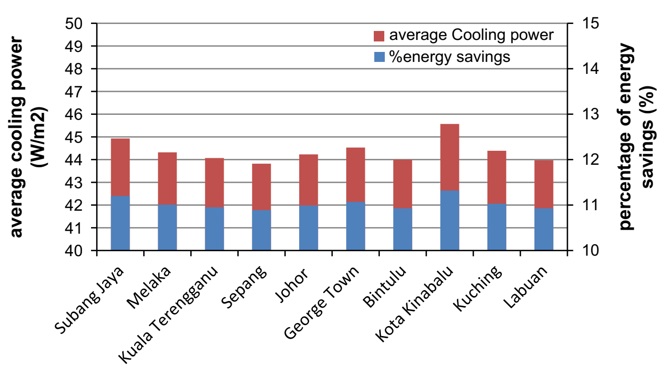

Fig. 13. Average cooling power and percentage of energy savings for different locations in Malaysia.

3.4. Discussion on cooling power potential in Malaysia

This section discussed the radiative cooling potential in Malaysia. Climate conditions throughout the Malaysian region are normally rainforest climate; it is typically hot and humid throughout the year and rain is heavy and frequent. This type of climate usually results in high relative humidity and overcast clouds in the night. In this condition, the dew point temperature and ambient temperature do not differ much. Therefore, the sky temperature also does not differ much from ambient temperature resulting in lower temperature difference between ambient and sky temperatures. Hence, the system can radiate less heat to the nocturnal sky resulting in low cooling power. But the system's performance will be constant since there is no significant change in the weather condition.

The estimation of energy savings for the radiative cooling system has been conducted. The cooling system usually operates from 8:00 P.M. to 6 A.M (10 h) and the power consumption for air conditioner is 1 kW. If a 2 m × 3 m radiator is used, the cooling system can save up to 25% power consumption for cooling purposes.

4. Conclusions

This research explained the cooling system configuration and implementation potential in Malaysia. The radiative cooling system is operated by using the flat-plate rooftop as a radiator to reject heat to the cooler nocturnal sky for cooling purposes by considering the potential of radiative cooling for energy savings.

For the calculation of the cooling power purposes, climate data are collected for analysis. The important parameters needed from the climate data are ambient and dew point temperatures. The sky temperature is determined by using a mathematical model as a function of dew point temperature. The study was conducted to determine the relationship between the cooling power and the temperature difference between ambient and sky temperatures. Analysis is done for different sky conditions, clear and covered. The cooling power obtained is only 43.9 W/m^2 on 2 December. This is when the sky is covered with clouds and the temperature difference is only 9.55 °C. Higher cooling power is achieved on 13 December with a cooling power of 48 W/m^2. This is when the sky is clear and the average temperature difference is 10.53 °C.

The radiative cooling potential in Malaysia is also determined by using the climate data for the year 2012 for 10 different cities, 6 from peninsular areas and 4 from Sabah and Sarawak. The results show that the radiative cooling can save up to 25% of the power consumption for cooling purposes. In conclusion, the implementation of the radiative cooling system for buildings in tropical climate, especially in Malaysia, is quite encouraging.

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